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Indian Ricegrass (*Oryzopsis hymenoides*) Germination Affected by Irrigation and Bagging During Seed Production

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*Seed dormancy is the primary factor limiting stand establishment of Indian ricegrass [*Oryzopsis hymenoides *(Roem. & Schult.) Ricker] in rangeland reseedings in western North America. Our objective was to determine if irrigation or bagging of plants during seed production affected dormancy of two Indian ricegrass accessions, the cultivar Paloma and the experimental population PI 478833. Bagging of inflorescences for research purposes is practiced because of susceptibility to shattering. In 1989, irrigated and nonirrigated treatments were applied, and seed was harvested on 28 July. In 1990, irrigation was applied as in 1989, but approximately half of each plant's panicles were enclosed in a brown paper bag. Seed was harvested 5 July from spring growth [seed production interval (SPI) 1], 10 August from regrowth since 7 June (SPI 2), and for Paloma unbagged only, on 10 August from regrowth since 5 July (SPI 3). In 1989, germination of Paloma relative to PI 478833 was greater (*$P < 0.01$*) with irrigation (76% versus 39%) than without (63% versus 51%). In 1990, SPI 1 irrigation and accession did not interact, but at SPI 2, germination of Paloma relative to PI 478833 was again greater (*$P < 0.05$*) with irrigation (74 versus 50%) than without (60 versus 46%). Irrigation did not affect germination of Paloma at SPI 3. In 1990, SPI 1 germination of PI 478833 relative to Paloma was greater (*$P < 0.01$*) with bagging (61% versus 40%) than without (41% versus 39%). The same trend was evident at SPI 2, where germination of PI 478833 relative to Paloma was greater (*$P < 0.01$*) with bagging (52% versus 62%) than without (44% versus 72%). Germination of Paloma was enhanced by irrigation, while germination of PI 478833 was favored by bagging. Researchers should be aware that these environmental factors may interact with accession to affect seed dormancy in Indian ricegrass.*

Keywords *Oryzopsis hymenoides*, seed production environment, seedling establishment

Indian ricegrass [*Oryzopsis hymenoides* (Roem. & Schult.) Ricker], a member of the Stipeae tribe, is an important native grass for livestock and wildlife in western North America. It is particularly abundant in natural stands on sandy sites from the Rocky

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Mountains west to the Sierra Nevada Mountains, the so-called Intermountain Region. The majority of the land in the region is government administered, and much was overgrazed at one time. Because native species are increasingly desired on ideological grounds, interest in this grass for artificial seedings in the region is great. However, the use of Indian ricegrass for this purpose has been discouraged because poor germination attributed to seed dormancy is common. Both mechanical and physiological mechanisms contribute to seed dormancy in this species (Huntamer, 1934). Seed dormancy is arguably desirable in established natural populations, but seed lots of high germinability are preferred for revegetation (Roundy & Call, 1988). Zemetra et al. (1983) suggested a combination of low-dormancy germplasm and scarification to overcome the problem of Indian ricegrass seed dormancy in revegetation projects. An improved understanding of the effects of the seed production environment on the control of dormancy may also contribute to the improvement of stand establishment.

Though no data are available for Indian ricegrass, considerable research has been conducted on the effect of temperature during seed maturation on dormancy in several other cool-season grass species. Seed dormancy (viability–germination) was 58% when detached culms of "Gulf" annual ryegrass (*Lolium multiflorum* Lam.) matured at 15°C for 28 days following anthesis, but 24% at a 27°C maturation temperature (Wiesner & Grabe, 1972). Averaged over two germination temperatures, "Fawn" tall fescue (*Festuca arundinacea* Schreb.) seed produced at 15°C had 13% germination, while seed produced at 27°C had 35% germination (Boyce et al., 1976). Probert et al. (1985) reported a positive linear relationship between seed maturation temperature and germination percentage in orchardgrass (*Dactylis glomerata* L.).

This research was stimulated by germination of five field harvest treatments ranging from 42% to 71% for experimental population PI 478833 and from 78% to 86% for cultivar Paloma. This seed was produced in research plots in North Logan, Utah, in 1988. This germination is considerably higher than the negligible germination characterizing most recently harvested commercial seed lots (Jones & Nielson, 1992a). Environmental variables such as irrigation and bagging of inflorescences, as practiced in the 1988 experiment, may exert major impacts on the expression of seed dormancy during seed development. Irrigation is routinely practiced in commercial seed production to increase seed set and yield, while bagging in research plots maximizes seed recovery of this species, commonly reduced by floral indeterminacy and shattering (Jones & Nielson, 1992b). Bagging affects light quantity, light quality, and temperature experienced by the maturing seed, which may indirectly affect seed dormancy. Edaphic factors such as soil moisture also likely influence seed dormancy, but few data are available (Bewley & Black, 1985). Our objective was to evaluate the effects of irrigation and bagging on germination of two Indian ricegrass accessions originally collected from native stands on the eastern slope of the Rocky Mountains, the highly indeterminate cultivar Paloma (Pueblo County, Colorado) and the moderately indeterminate experimental population PI 478833 (Yellowstone County, Montana).

Materials and Methods

Seedling plants of Indian ricegrass were transplanted 18 August 1987 at North Logan, Utah, on a Millville silt loam soil [coarse-silty, carbonatic, mesic Typic Haploxerolls (2–4% slope)]. Plots were located at 41°46′00″N, 111°49′38″W at an elevation of 1408 m. Average annual precipitation at the site is 441 mm. Average seasonal precipitation is 39 mm (June), 11 mm (July), and 24 mm (August). Average annual temperature is 10.0°C.

Average seasonal temperature is 17.8°C (June), 22.8°C (July), and 21.7°C (August). Plants were arranged on 1-m centers in a split-plot design with four replications. Paloma and PI 478833 accessions served as whole plots, and irrigation treatments (irrigated or unirrigated) as subplots. Each whole plot consisted of four rows of five seedlings, and each subplot consisted of two rows of a whole plot. The experiment was bordered by a single row of PI 478833. During irrigation periods, plants in irrigated subplots were watered to field capacity three times weekly. A gravity-flow system directed water from a nearby canal to circular irrigation basins around each plant. In 1989, precipitation was 22 mm in June and 0 mm in July. Ambient low (high) temperatures averaged 10.9° (25.0°C) in June and 17.2° (33.1°C) in July.

On 19 June 1989, all plants in the experiment were clipped at 0.15 m above the soil surface to delay seed production. Plots were irrigated from 19 June to seed harvest on 28 July. Seed was threshed by hand, cleaned with a "South Dakota" blower, bulked within a subplot, and stored at room temperature until germination testing the following May. Cleaning with the blower assured high viability of seed because it removed poorly filled seed. Seed mortality between harvest and germination testing was considered negligible because of the longevity of this species' seed (Rogler, 1960).

Using the same plots as in 1989, seed was harvested in 1990 from three seed production intervals (SPI) designated SPI 1, SPI 2, and SPI 3. Data for each interval were analyzed independently. One row in each subplot was reserved for SPI 1 in the spring (initial growth) and SPI 3 in the summer (regrowth of the SPI 1 plants). Approximately half the panicles of plants in SPI 1 rows were gathered together and enclosed in a brown paper bag on 7 June. Harvest of bagged and unbagged seed of SPI 1 was made on 5 July. Harvest of SPI 3 was taken from regrowth of the same plants on 10 August without bagging. Only Paloma was harvested at SPI 3 because of insufficient regrowth of PI 478833.

The remaining row in each subplot was reserved for SPI 2. These plants were clipped on 7 June to delay flowering, bagged on 6 July, and harvested on 10 August, the same date as SPI 3. The experiment was irrigated in 1990 as in 1989 from 7 June to 10 August, the duration of seed production evaluated in 1990. In 1990, precipitation was 45 mm in June, 5 mm in July, and 11 mm in August, considerably wetter than 1989. Ambient low (high) temperatures averaged 11.3° (26.2°C) in June, 16.3° (31.8°C) in July, and 14.9° (30.6°C) in August, comparable to 1989. All 1990 seed was handled as in 1989.

Germination tests were conducted with one hundred seeds planted with a vacuum seed head on 250 g of sand in a 110 × 110 × 35 mm plastic germination box. The seeds were covered with a nontoxic steel blue germination blotter (Anchor Paper, St. Paul, Minnesota), over which was poured 60 mL of tap water. The boxes were closed with fitted plastic lids. Soil matric potential was approximately –0.17 MPa (R. W. Brown, personal communication), which is in the desirable range for germination in field-collected soil (Blank & Young, 1992). Seeds were germinated with or without prechilling in four boxes (subsamples) each per subplot. In 1989, nonprechilled seeds were germinated in the dark at 15°C, and germination was recorded after 35 days. Prechilled seeds were placed in the dark at 5°C for 21 days and then transferred to a dark 15°C chamber for a 14-day germination period. Prechilling increases germination of recently harvested Indian ricegrass seed (Clark & Bass, 1970; Jones & Nielson, 1992a). The procedure for 1990 seed was identical, except nonprechilled data were not collected. Percent germination values were arcsine transformed (Sokal & Rohlf, 1981) before analysis. Seed weight was calculated from 1000-seed samples from all harvests in 1990. All effects except replications were considered fixed for analysis of variance.

Results and Discussion

Indian ricegrass lacks a vernalization requirement for flowering and is highly indeterminate (Jones, 1990). The cultivar Paloma is more indeterminate than experimental population PI 478833 and produces more vegetative and reproductive dry matter than PI 478833 in regrowth. Unlike most other cool-season grasses, a large portion of Indian ricegrass regrowth from summer clipping is reproductive. Despite repeated clipping, flowering may continue for the entire growing season as long as soil moisture is available. This allows the experimenter to collect multiple data sets in a single year by harvesting seed from sequential SPIs. These may be considered different seed production environments.

In 1989, irrigation increased germination of Paloma by 13% ($P < 0.10$) but decreased germination of PI 478833 by 12% ($P < 0.10$), resulting in a significant ($P < 0.01$) population × irrigation interaction (Table 1). Nonprechilled germination was under 5% for all population × irrigation combinations. Therefore, nonprechilling was omitted in 1990, and all germination results reported are after prechilling.

Results for irrigation in 1990 were compatible with 1989 results. While irrigation did not affect germination at SPI 1 (Table 1), the means followed the same trend as in 1989. At SPI 2, irrigation significantly ($P < 0.01$) increased germination of Paloma by 14% but did not affect germination of PI 478833. This caused a significant ($P < 0.05$) population × irrigation interaction as in 1989. Though irrigation did not decrease germination of PI 478833 at SPI 2 as in 1989, the effect was still less positive than the effect on Paloma. Irrigation at SPI 3 did not increase germination of Paloma, but the data reflected the trend of the previous three harvests.

Bagging significantly ($P < 0.05$) increased germination of PI 478833 by 20% at SPI 1 and by 8% at SPI 2 (Table 2). Bagging had no effect on germination of Paloma at SPI

Table 1.

Prechilled Germination of *Oryzopsis hymenoides* Cultivar Paloma and Experimental Population PI 478833 as Affected by Irrigation during Seed Production in 1989 and at Seed Production Intervals (SPI) 1, 2, and 3 in 1990

	1989**		1990 (SPI 1) NS	
Accession	Nonirrigated	Irrigated	Nonirrigated	Irrigated
Paloma	63	76^{+}	37	42 NS
PI 478833	51	39^{+}	53	48 NS
	1990 (SPI 2)*		1990 (SPI 3) NS	
	Nonirrigated	Irrigated	Nonirrigated	Irrigated
Paloma	60	74**	59	70 NS
PI 478833	46	50 NS	ND	

Means are based on four field replications and two bagging treatments, each with four laboratory subsamples. Values in percent.

Comparison of nonirrigated and irrigated treatments within a population or population × irrigation treatment interaction is nonsignificant ($P > 0.10$) (NS) or significant at $P < 0.10$ (+), 0.05 (*), and 0.01 (**).

ND, Not determined [PI 478833 not harvested at 1990 (SPI 3)].

Table 2.

Prechilled Germination of *Oryzopsis hymenoides* Cultivar Paloma and Experimental Population PI 478833 as Affected by Bagging during Seed Production in 1990 at Seed Production Intervals (SPI) 1 and 2

	1990 (SPI 1)**		1990 (SPI 2)**	
Accession	Unbagged	Bagged	Unbagged	Bagged
Paloma	39	40 NS	72	62**
PI 478833	41	61*	44	52*

Means are based on four field replications and two irrigation treatments, each with four laboratory subsamples. Values in percent.

Comparison of unbagged and bagged treatments within a population or population × bagging treatment interaction is nonsignificant ($P > 0.10$) (NS) or significant at $P < 0.05$ (*) and 0.01 (**).

1, but it significantly ($P < 0.01$) decreased germination by 10% at SPI 2. Thus, bagging had a more positive effect on germination of PI 478833 than Paloma at both SPI 1 and 2, resulting in significant ($P < 0.01$) population × bagging interactions.

The cause of lower germination rates of Paloma relative to PI 478833 at SPI 1 is unclear. This result disagrees with other data presented here, our previous unpublished data, and results published earlier (Jones & Nielson, 1992a). This anomaly indicates that environmental variables may have unpredictable effects on rankings of accessions for germination among seed production environments. Bagging, through its effect on temperature and light intensity and quality, and soil moisture are two variables measured here that contribute to the seed production environment.

At SPI 1 seed weight was reduced ($P < 0.01$) from 4.00 to 3.66 mg (9.5%) by bagging. The accession × irrigation interaction was also significant ($P < 0.05$). Irrigation increased seed weight of Paloma from 4.30 to 4.47 mg (4.0%) but decreased seed weight of PI 478833 from 3.33 to 3.21 mg (3.6%). In contrast to SPI 1, bagging at SPI 2 increased ($P < 0.01$) seed weight from 3.82 to 4.11 mg (7.6%). Effects of irrigation and interactions between accession, bagging, and irrigation were absent. At SPI 3, irrigation did not affect seed weight of Paloma.

Based on 1990 data, differences in germination were not closely correlated with the effects of bagging or irrigation on seed weight described above. Therefore, any effect of bagging or irrigation on seed weight cannot account for associated effects on germination. While irrigation increased Paloma germination ($P < 0.01$) at SPI 2, irrigation had no effect on seed weight ($P > 0.10$). Bagging increased germination of PI 478833 at SPI 1 in spite of reduced seed weight ($P < 0.01$). Bagging increased seed weight at SPI 2 ($P < 0.01$) without interaction with accession ($P > 0.10$), while increasing germination of PI 478833 ($P < 0.05$) and decreasing germination of Paloma ($P < 0.01$).

The effects of irrigation and bagging were highly genotype dependent. Irrigation increased germination of Paloma in two of four trials, but decreased germination of PI 478833 in one of three trials. Bagging decreased germination of Paloma in one of two trials, but increased germination of PI 478833 in both of two trials. We conclude that Paloma is more responsive to irrigation, whereas PI 478833 is more responsive to bagging. The most probable effect of bagging on germination is through increased temperature, but this variable was not measured. Greater control of the seed production environment could increase germination of harvested seed. For example, irrigation may increase germination of some accessions, such as Paloma. Likewise, choosing warmer sites may be desirable with others, for example, PI 478833.

Still unexplained is why germination was so high in seed produced in 1989 and 1990, as well as for the 1988 data that originally prompted this study. Blank and Young (1992) also reported up to 83% germination of a 32-month-old seed lot of the cultivar Nezpar. In contrast, thirteen commercial prechilled seed lots of Paloma, PI 478833, and Nezpar ranged in germination from 6% to 39% (Jones & Nielson, 1992a), levels more suggestive of the long-term negative experience with this species. These seed lots ranged from 4 to 19 years of age, with the older seed lots generally germinating better than the newer seed lots, a result also reported by Rogler (1960). Additional research should be conducted to identify factors responsible for the dramatic differences in dormancy among seed lots of the same genotype.

In evaluating hundreds of populations of Indian ricegrass, we have found genotype has a large effect on seed dormancy (Jones, 1990). Besides these genetic effects, research reported here indicates environmental factors during seed maturation play an important role in regulation of seed dormancy. To find populations with reduced seed dormancy suitable for deliberate revegetation, many populations must be screened. Seemingly superior genotypes should be evaluated in several seed production environments to clarify their suitability for revegetation before recommendations are made for this purpose.

Both control of genotype and seed production environment have the potential to improve stand establishment. The considerable amount of information on seed conditioning is also relevant (Jones, 1990; Jones & Nielson, 1992a). Obviously, these three strategies are not mutually exclusive (Zemetra et al., 1983).

While seed dormancy is a natural feature of this species and likely confers an adaptive advantage, selection for genotypes low in seed dormancy is not necessarily undesirable. Seed polymorphisms (different sizes and shapes) within an accession exhibit differences in seed dormancy (Young & Evans, 1984). These polymorphisms may be produced on separate plants and therefore can be considered genetically distinct. A combination of genetically controlled seed dormancy levels in a seeding may be the best approach for long-term maintenance of a stand. Low-dormancy seed would give rise to initial establishment to improve prospects of successful revegetation, while high-dormancy genotypes would still be present in the seed bank for eventual germination when conditions permit. Actual mixing of polymorphisms with greatly different levels of seed dormancy within a cultivar would probably lead to dimunition of the more dormant seed during the generations of seed increase leading to commercial seed production. Therefore, a practical approach would be to plant a mixture of cultivars with characteristic levels of dormancy.

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